NASA FACTS

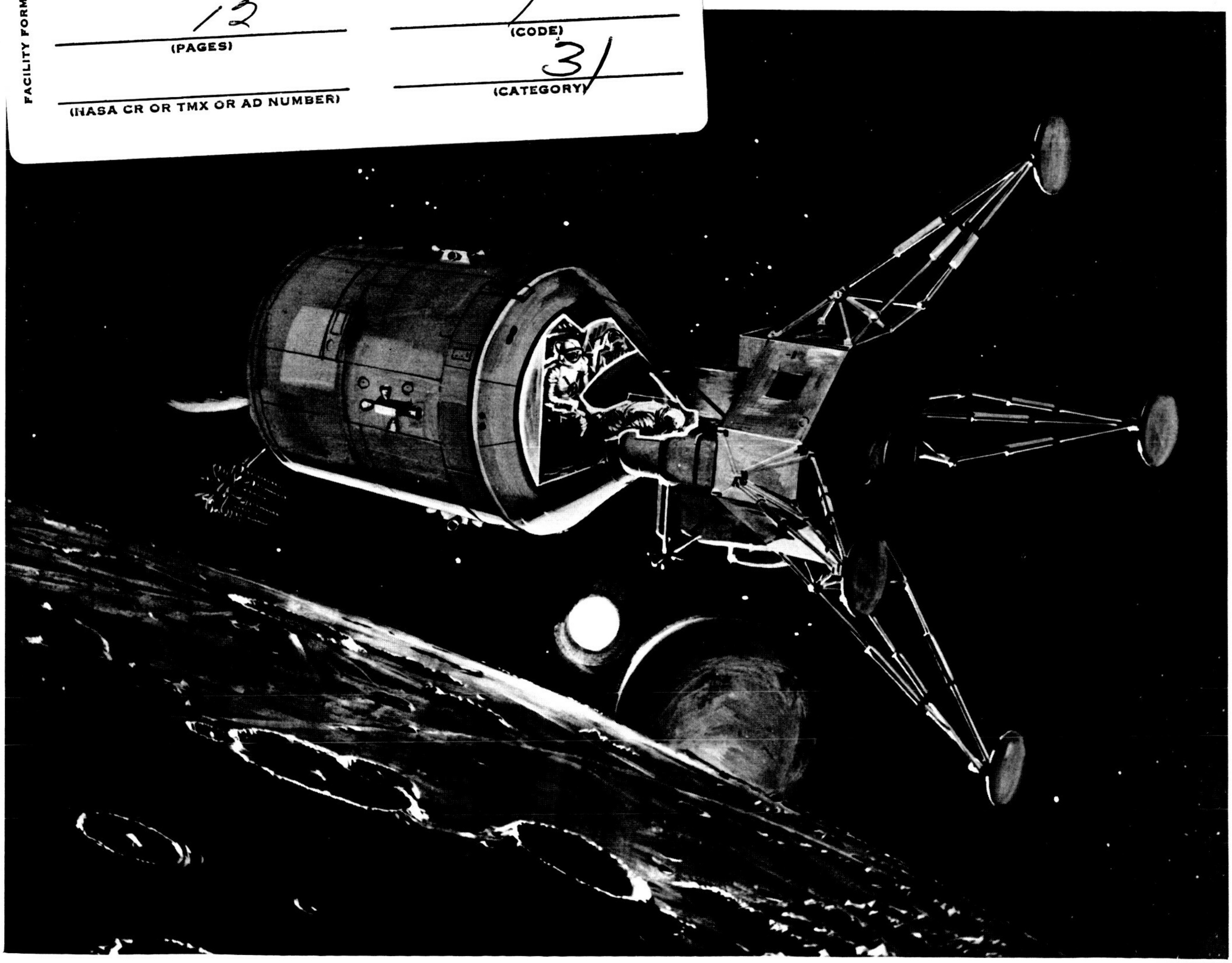
An Educational Services Publication of the
National Aeronautics and Space Administration

Vol. III, No. 1

MANNED SPACE FLIGHT

PROJECT APOLLO

50



(ILLUSTRATION BY NORTH AMERICAN AVIATION)

NEXT STOP, THE MOON—Two astronauts transfer into LEM (Lunar Excursion Module) to descend for exploration of the moon.

PROJECT APOLLO

Project Apollo is Step 3 of NASA's manned space flight lunar landing program. Its goal: to put men on the moon and return them safely to earth by the end of this decade.

In Step 1, Project Mercury paved the way by developing one man space vehicles and techniques for their use. Step 2 is Project Gemini, using two-man spacecraft, for longer orbital missions and for developing the technique of rendezvous and docking, during which two space vehicles are maneuvered close together and joined or "docked."

The technique of orbital rendezvous—in orbit around the moon—will be a key maneuver in Project Apollo to achieve lunar landings.

PROJECT APOLLO'S GOAL

Major elements in basic planning for Project Apollo included:

- Design and construction of a blunt-cone spacecraft different from the bell shaped Mercury and Gemini vehicles.
- Development of a powerful launch vehicle, the Saturn V, with 7.5 million pounds booster thrust, equal to that of 21 Atlas boosters. (Atlas was the launch vehicle for Mercury manned flights.)
- The Lunar Orbit Rendezvous (LOR) flight plan for the moon landing mission.

LOR was chosen after careful review of three possible methods, the other two being (1) direct flight from earth surface to moon surface and (2) Earth Orbit Rendezvous (EOR), launching two payloads from the earth and joining them in earth orbit into a single spacecraft capable of the moon journey. LOR was selected: it calls for launch of one spacecraft from earth to lunar orbit, and detachment of a Lunar Excursion Module to land on the moon and then return to the moon-orbiting vehicle. This reduced sharply the requirement for thrust capability as compared with landing the entire spacecraft assembly on the lunar surface, as in the direct and EOR methods.

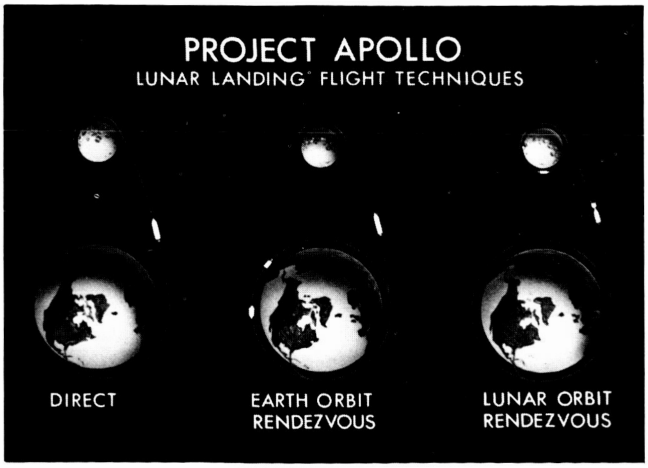
In fact, LOR reduced the total weight requirement for the lunar bound spacecraft, leaving earth, to about 45 tons, as compared with 100 tons for an EOR vehicle. Also, instead of two big boosters for EOR, the LOR method requires only one. Not only fuel but time will be saved, also a great deal of expensive hardware. These factors made LOR the best choice.

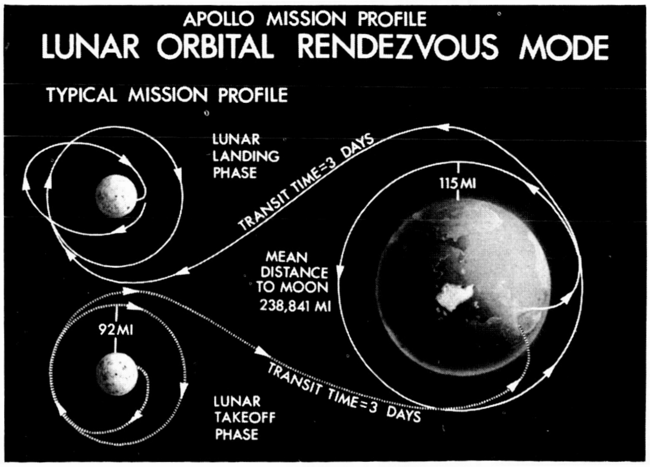
Apollo hardware—launch vehicles, spacecraft, and their instrumentation—is under development today.

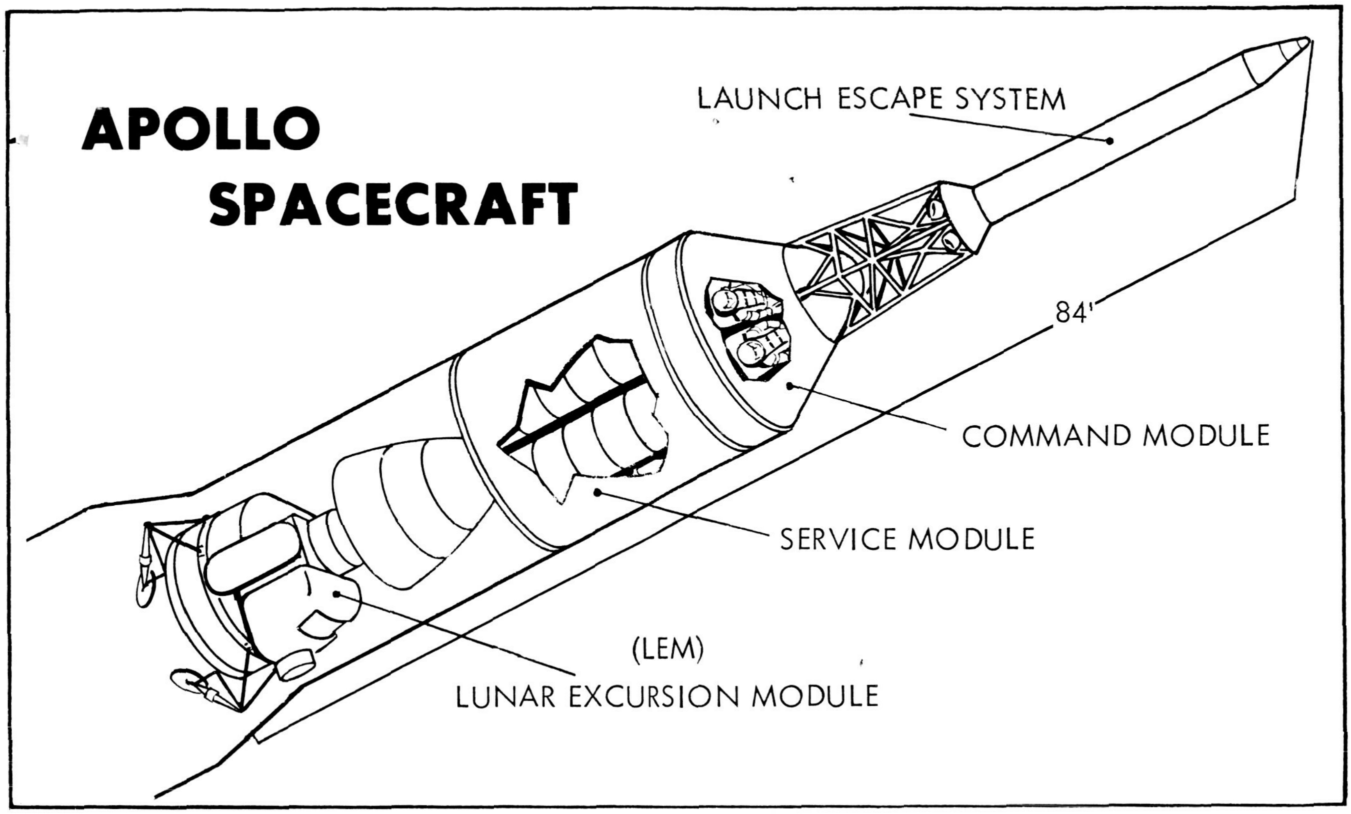
Astronauts meanwhile are in training for the lunar touchdown goal. Barring unforeseen setbacks, Project Apollo will fulfill the late President Kennedy's timetable (in his message to Congress in May 1961) and meet the man-on-the-moon goal he gave America—"within this decade."

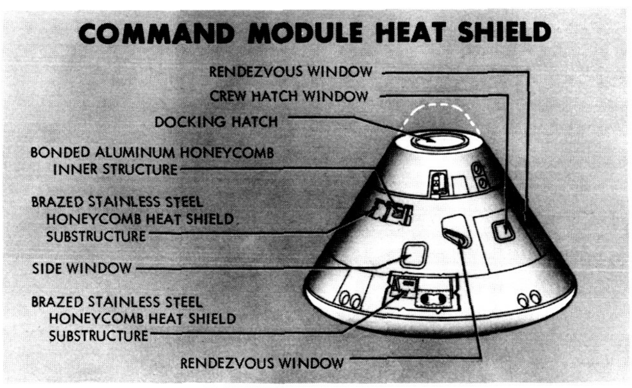
APOLLO SPACECRAFT

The Apollo spacecraft is to be 84 feet tall and weigh about 45 tons. It is divided into









three modules (separable units or "blocks"), an adapter, and a launch escape system.

COMMAND MODULE

First is the Command Module (CM), the only section that returns to earth. It contains the crew's living compartment, plus all controls for the various in-flight maneuvers. Shaped like a flattened cone, this module has a bottom width of 13 feet and stands about 11 feet high. Take-off weight is about 11,000 pounds. The double walled pressurized chamber has three windows in front of the astronauts' couches, and two side windows for views into space.

Similar to Gemini, the Apollo Environment Control System (ECS) supplies pure oxygen in the cabin at 5 psi (pounds per square inch), air conditioned to a temperature of approximately 75° with a humidity index between 40% and 70%.

More elaborately equipped for human comfort than either the Mercury or Gemini spacecraft, the Apollo CM is a compact version of a pilot cockpit for three astronauts.

The Apollo crew will be in touch with earth by television as well as radio.

LAUNCH ESCAPE TOWER

Perched on top the Command Module is a Launch Escape System tower with rocket motors, much like that of Mercury, which is 34 feet tall and weighs 6,600 pounds. This tower and motors give the launch pad Apollo spacecraft, without its booster, a total height of some 84 feet—almost as tall as the combined Mercury-Atlas vehicle that orbited John Glenn.

The tower and motors are jettisoned after the launch vehicle's second stage ignites. The system would be used only in a launch emergency situation.

SERVICE MODULE

Beneath the crew's command section is the Service Module, a cylindrical unit 128 feet in diameter and 14 feet tall, weighing 50,000 pounds. Besides the electrical power supply equipment, the main apparatus within is the primary propulsion system, which produces 22,000 pounds of thrust. Its stop-and-restart engine is used for several important maneuvers—mid-course correction during moon approach, slowing down to go into lunar orbit, takeoff from lunar orbit to earth, and mid-course corrections while earthbound.

Having fulfilled all these functions during the round trip, the service module is finally jettisoned just before the Command Module reenters the earth's atmosphere.

ADAPTER

Under the Service Module, at launch, is the section that acts both as the adapter which fits the Apollo on top its launch rocket, and also as the housing for the LEM (Lunar Excursion Module), the lunar landing vehicle.

The adapter section is a truncated conical shell 29 feet tall and 13 feet wide at the top. At the bottom it flares out to a diameter of 21.6 feet, in order to match the width of the Saturn V booster's IV–B top stage. Weight of the adapter housing is 4,000 pounds.

LUNAR EXCURSION MODULE

The LEM, which weighs approximately 30,000 pounds, is the flight unit that will detach from the orbiting CSM (Command and Service Modules) and descend to the moon's surface with two of the three astronauts aboard. Called the "bug" because of its appearance, it has two windows, a tubular "mouth" for the astronauts to climb in and out, and four spidery "legs" for sturdy support after lunar touchdown.

The LEM has its own complete guidance, propulsion, computer, control, communications, and environmental control systems, all with at least one and sometimes two backups. These precautions are necessary because landing on the moon will be the lunar mission's most critical phase.

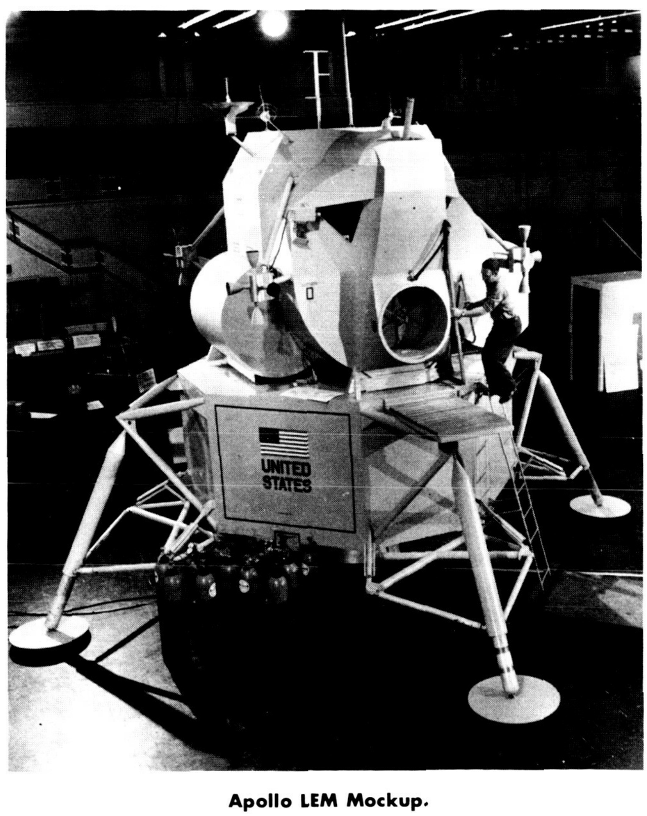
The LEM's propulsion system is throttleable—its rocket engine's thrust power can be varied from low to high (1,050 pounds to 10,500 pounds) in order to control the lunar touchdown flight with great precision. The pilots will depend on this rocket to land on the moon.

The final descent can be slowed to a featherlike drift. But if the LEM should drop like a stone, its four jointed steel-truss legs can take up the landing shock without harm to the craft or crew. The legs are also designed to land on slopes up to 12 degrees in slant, or to retain balance if one or two legs sink into a layer of dust 12 inches deep.

The LEM is a two stage vehicle. The bottom stage contains the rocket engine and legs for lunar landing. This is detachable and forms the "launch platform" for the upper stage, which is a cabin for the astronauts. Attached to the upper stage, or astronauts' cabin, is the rocket engine to propel the stage from the lunar surface to the awaiting CSM.

GUIDANCE AND NAVIGATION

The moonbound Apollo's space navigation system includes two relatively conventional



Apollo LEM Mockup.

units—inertial guidance platform, and flight pattern computer. A third unit will be an optical space sextant with which the astronauts will take sightings of the earth, moon, and reference stars to check out their position before each maneuver with their rocket engines, during any leg of the round trip.

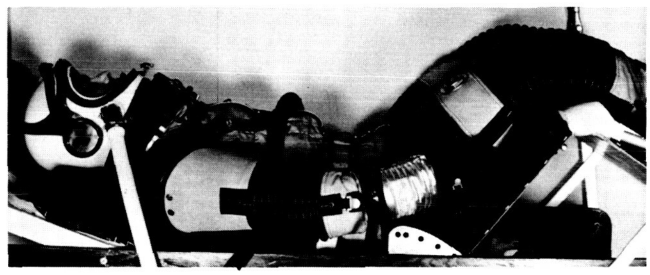
ASTRONAUT WARDROBE

The Apollo crewmen will have a changeable wardrobe for wear at different times. On the outward bound trip, two of the men (in rotation with the third) will relax in "constant wear garments," a cross between ski pants and long underwear.

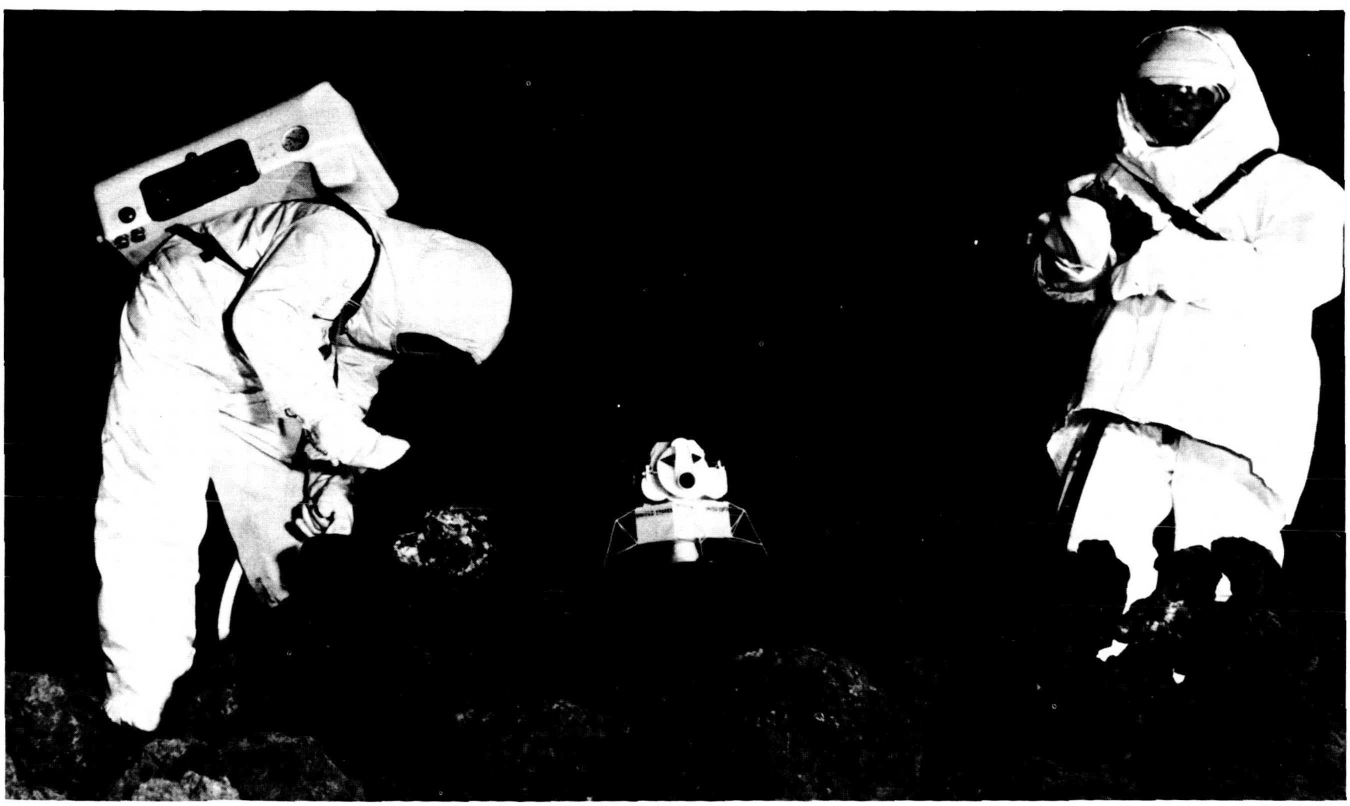
The third man will be in the Apollo space suit featuring "accordion" joints (bellows principle) for flexible ease in walking, bending, or moving his limbs, and a helmet with a pivoted visor for quick closing and sealing.

The same space suit will be worn by the two LEM astronauts who step forth on the moon. But underneath will be a special undergarment interwoven with a fine network of water-circulating tubes to carry away body heat. Over the entire space suit is worn a "thermal garment," or a white monk-like coverall with hood, protecting the astronaut from the airless moon's blistering sunshine. Finally, a "meteoroid cape" on his back will fend off micrometeoroid dust which may rain down on the moon at high speed. Bigger bullet-like meteoroids that would penetrate the cape are calculated to be rare.

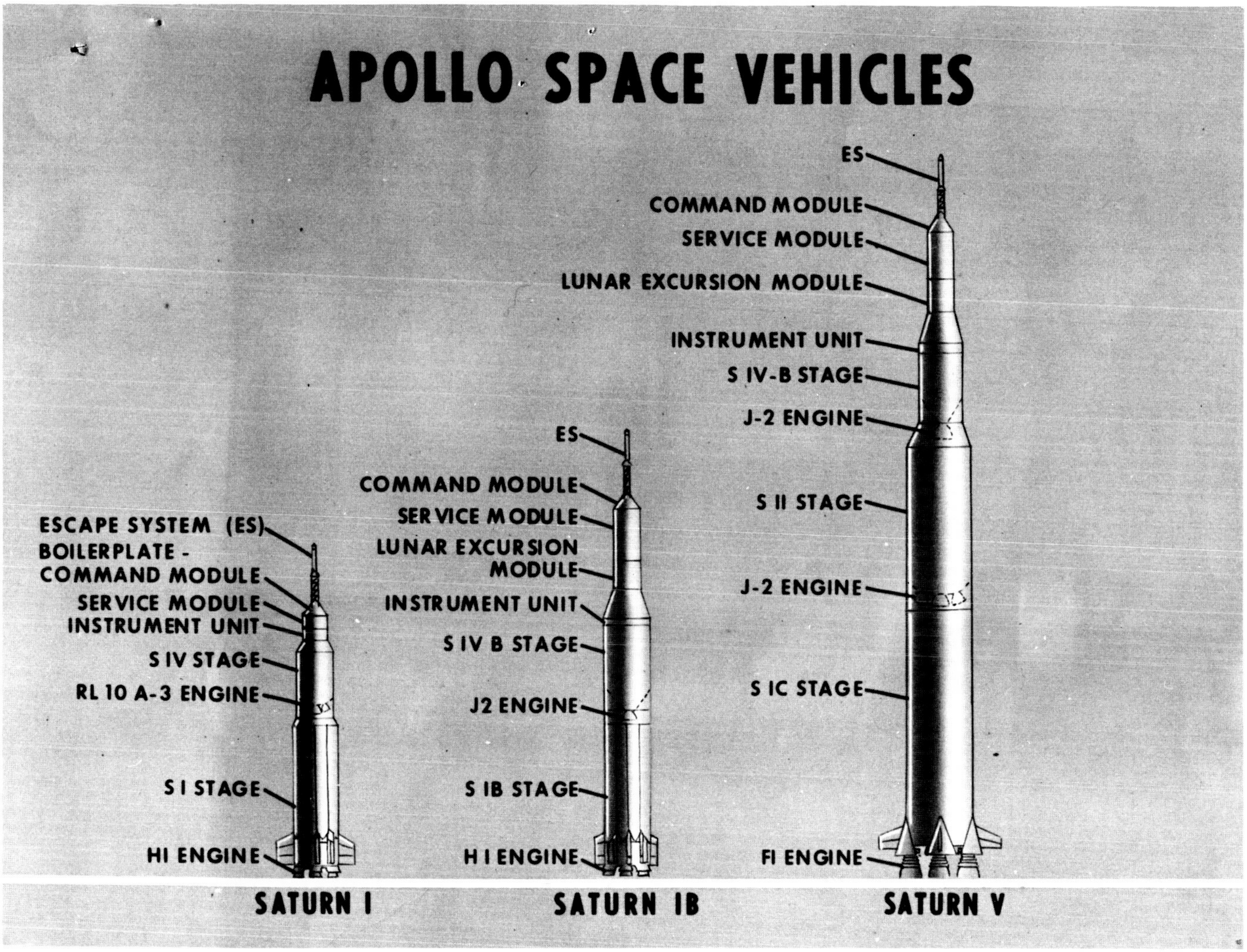
An important added unit of the Apollo space suit system will be the strap-on backpack for lunar exploration, including 4-hour oxygen supply, two-way radio, heat-dumping radiator, and dosimeter (radiation gauge). Partial radiation protection is built into the space suit fabric.



Apollo pressure suit being tested.



Astronauts demonstrate prototype thermal over garments designed to protect men on moon from direct rays of sun and radiated heat.



LAUNCH VEHICLES

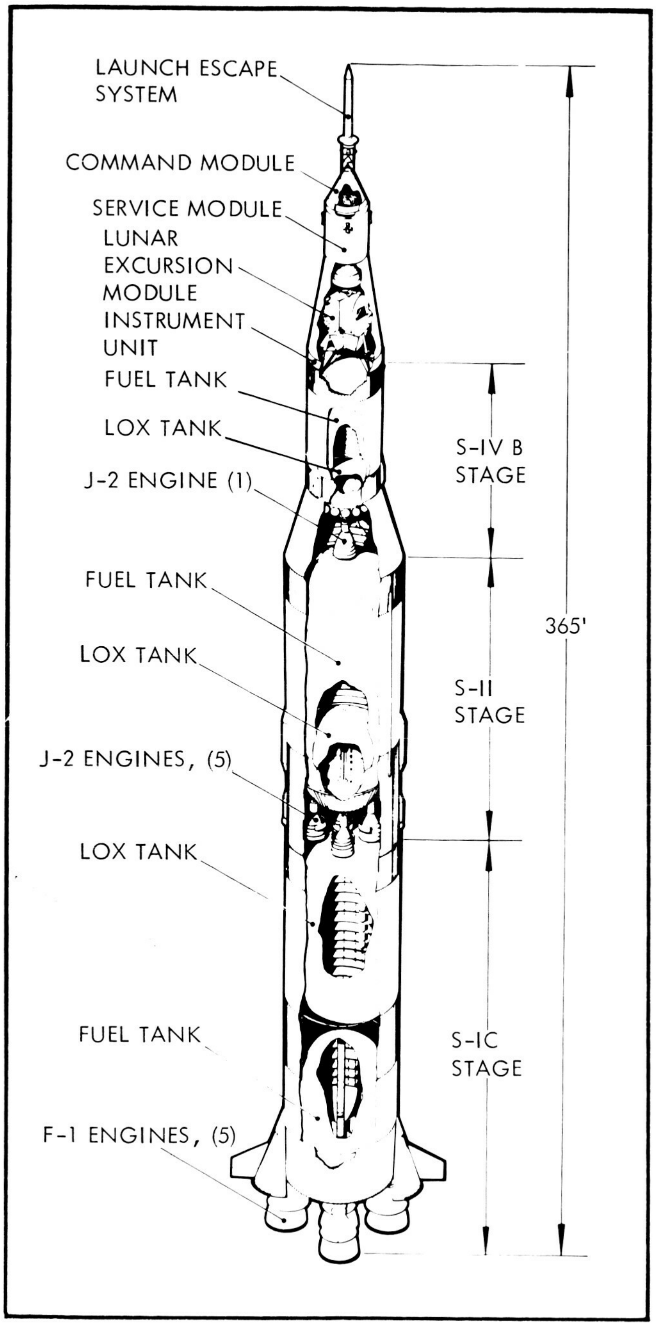
Three Saturn launch vehicles will be used in the Apollo Program.

Saturn I develops 1.5 million pounds of thrust in its S–1 first stage through the clustering of eight H–1 rocket engines burning RP–1 (refined kerosene) and LOX (liquid oxygen). Its S–IV second stage has six RL–10–A–3 engines burning liquid hydrogen and LOX, producing 90,000 pounds total thrust. With a diameter of 21.5 feet and standing 120 feet tall, without spacecraft, this two-stage vehicle delivers a payload of 11 tons (22,000 pounds) into low earth orbit.

Saturn I has placed into orbit the Command and Service Modules of the Apollo spacecraft in unmanned test flights and the Pegasus micrometeoroid technology satellites.

The Saturn IB will have an improved first stage version of the Saturn I, and a new and more powerful second stage—the S–IV B. The Saturn IB will launch the first manned Apollo flights into earth orbit.

The S–IV B stage has one J–2 liquid hydrogen-LOX burning engine of 200,000 pounds thrust. Low earth orbit payload for the Saturn IB will be 17.5 tons (35,000 pounds), enough to launch the complete three module Apollo spacecraft into earth orbit to allow the crew to practice rendezvous and docking.



SATURN V.

Saturn V will be a vehicle of gigantic size and power. The first stage, the S–I C, will have a diameter of 33 feet and will be powered by a cluster of five F–I engines, each developing thrust equal to the Saturn I's 1.5 million pounds, for a total of 7.5 million pounds. An S–II second stage clustering five J–2 engines will furnish 1 million pounds of thrust. On top will be a third stage S–IV B, identical with the Saturn IB's second stage.

Standing about 281 feet high, this immense three stage booster, topped by the three module Apollo plus escape tower, will stand 365 feet high at the launch pad and weigh 6 million pounds fueled before a moon flight.

The mightly Saturn V launch vehicle will be able to shove 140 tons (280,000 pounds) into earth orbit at a speed of 5 miles per second (mps), and hurl 47.5 tons of escape velocity payload away from earth at 7 mps. This means that both the Apollo spacecraft and third stage go into parking orbit, after which the S–IV B re-ignites and adds speed of 2 mps to hurl the spacecraft on its way.

Saturn I in launch position.

UNMANNED MOON PROBES

An important preliminary to the manned Apollo flight is the unmanned lunar spacecraft program.

The highly successful Rangers VII, VIII, and IX, with their remarkable moon close-up pictures, will be followed by Surveyor vehicles which will be "soft-landed" on the moon, to send close-up TV pictures of the lunar surface and also analyze soil samples.

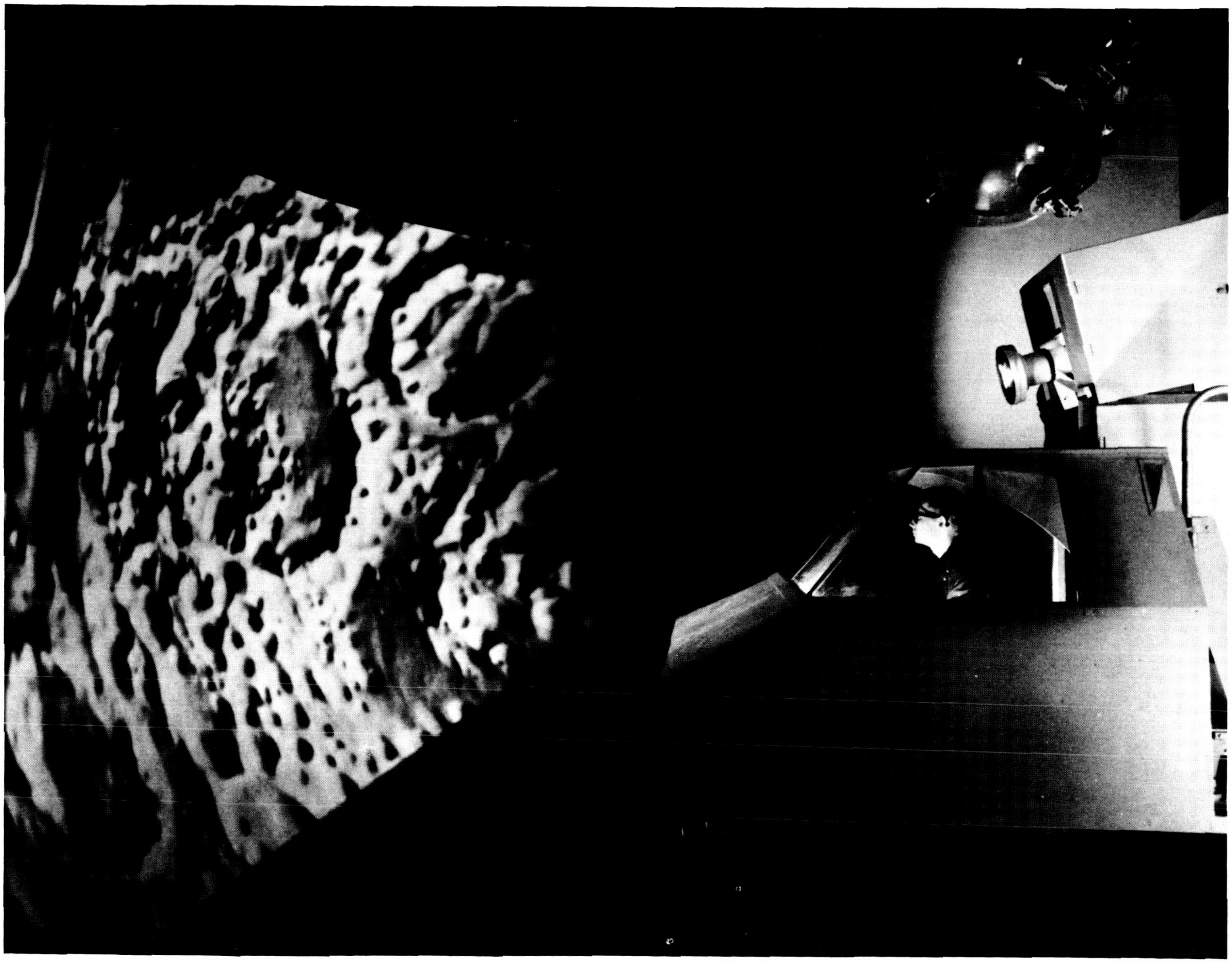
Another series of spacecraft, the Lunar Orbiters will go into low moon orbit 22 miles above the surface to photograph many lunar regions.

TRAINING

Astronaut training for the Apollo Program includes the "basic space training" of Projects Mercury and Gemini. Also, new Apollo specialties are being added from time to time. Among them:

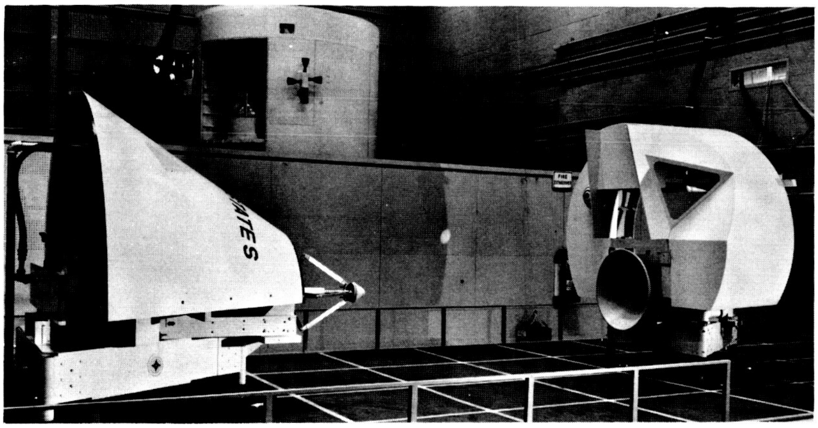
- "Moon Trips" in simulator trainers that create the realistic illusion of travel through space, descent on the moon, and return to earth.

- "Lunar Obstacle Course," a 328-foot-wide simulation of the moon's rugged surface, complete with craters up to 50 feet wide and 15 feet deep, large boulders, a dust layer, and fissures over which to jump. A suspension harness reduces an astronaut's weight to the moon's value (1/6th earth weight) of 25 or 30 pounds. The trainee, making long leaps across this moon-patch, experiences con-



(BOEING COMPANY)

Space flight simulator, with image of the moon on left, used for determining what man can and cannot do in controlling spacecraft during actual missions.



LUNAR DOCKING—Mockups of Apollo command and lunar excursion modules used for rehearsing space docking technique.

ditions near to those he will meet on the moon.

- "Space Suit Workouts," during which astronauts wear experimental Apollo pressure garments to practice walking, bending, opening of visor, and the like.

MOON FLIGHT TRACKING SYSTEM

A network of tracking stations was established around the world for Project Mercury and augmented for Gemini. Ground stations and ships are included.

All these stations will follow the Apollo spacecraft at the beginning and end of the lunar mission, during the first launch into earth orbit, and during the final reentry after the moon trip is finished.

As soon as the spacecraft leaves earth orbit beyond their range, tracking will switch to stations located at Goldstone, California, Madrid, Spain, and Carnarvon, Australia. These stations are situated about 120° apart (going east and west), so that as the rotating earth cuts off one station's direct line contact with a deep space vehicle, the next station rises above the horizon and takes over.

An unbroken day and night surveillance of the Apollo spacecraft can then be kept by those stations. The huge 85 foot dish antennas and sensitive equipment are similar in appearance to those which have received faint signals from millions of miles away in space (Mariner to Venus and others.)

When the returning Apollo speeds toward earth at 25,000 mph, the chain of land and ship tracking stations will gear in to monitor the vital reentry and recovery operation.

LUNAR LANDING FLIGHT

Sometime around the end of this decade, America will send astronauts to the moon. At countdown time zero, the 365-foot Apollo Saturn V vehicle will lift off the pad. The first and second stages will burn all their propellants but the third stage will burn only enough to place itself and the three module Apollo spacecraft in "parking" orbit about 100 miles high.

A little later, when the lunar "launch window" (best period of time for takeoff) is open, according to earth computers, the third stage will refire, add speed, and escape from the earth.

Now on their way to the moon, the three man crew reorient the segments of their spacecraft and discard the third stage of the launch vehicle.

A mid-course correction may be made if their lunar trajectory (line of flight) is other than the one desired. This correction is made with the Service Module's 22,000-pound-thrust rocket engine. About 2¼ days after launch, the earth's gravitation slows the spacecraft down gradually, from 24,300 mph to 6,300 mph.

Some 64 hours after leaving earth, the spacecraft nears the moon and the astronauts apply Service Module propulsion system retro power for about 6 minutes to slow down to 3,600 mph, allowing the craft to swing into a lunar orbit about 83 miles high. For the lunar landing, two men will crawl into the LEM, which later detaches from the CSM mother ship.

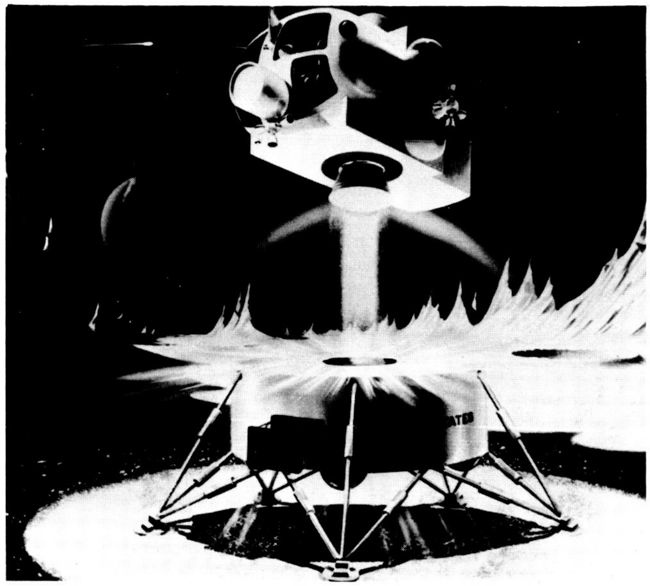
After about 68 hours of mission time, LEM separates from the CSM, with a difference in velocity of about 3 mph, and moves away 735 feet. The descent engine puts LEM into a transfer orbit and a velocity of 3,500 mph is achieved. The LEM then coasts until an altitude of about 49,500 feet is reached and powered descent begins. Powered descent continues to the hover altitude of 200 feet when either a manual or automatic hover-to-touchdown procedure is initiated. In either method, the engine is cut off at a LEM altitude of about 15 feet giving the LEM a lunar impact speed of about 3 mph.

The sturdy vehicle drops to the lunar surface with a jar scarcely felt by the astronauts.

Two United States citizens stand on the moon! It will be a great moment, perhaps televised to millions of Americans watching at home over the nation's TV network.

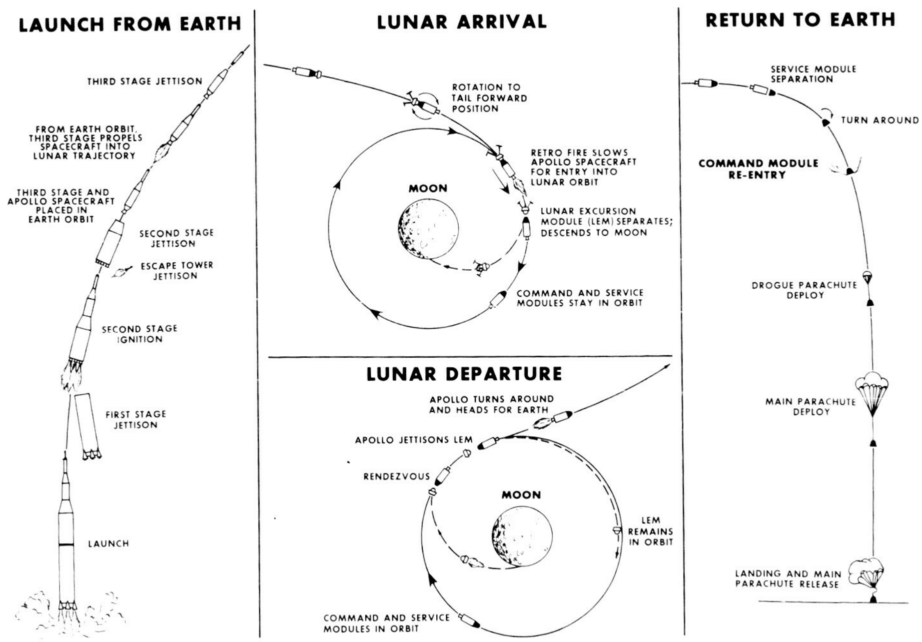
The stay may be as short as 4 hours, and probably not longer than 34. Each of the two men, in turn, will step from the LEM in his special "moon suit" to carry out various scientific tasks.

When the time arrives for rejoining the orbiting Command and Service Module the lower stage of LEM serves as a launching pad, and is left behind on the surface of the moon.



Artist's rendering showing powered Lunar Excursion Module ascent from surface of the moon.

Timing the launch to coordinate with the CSM, the LEM ascent stage will then meet it 83 miles high for rendezvous and docking. After the three astronauts are once again together in the CSM, the LEM is jettisoned and left in moon orbit The Service Module's rocket engine is ignited to build up lunar escape velocity of 5,460 mph. Some 29,000 miles outward, they pass out of the moon's gravitational field. Then, under the earth's pull, the CSM returns at ever



Sequence of major events in Apollo lunar landing mission.

mounting speed that, 198 hours after launch has reached the same velocity with which they left earth—about 24,600 mph.

After using the Service Module's propulsion for final course corrections, this segment is jettisoned and the Command Module is left by itself as it plunges into the earth's atmosphere.

With a velocity of 24,600 mph, reentry will be trickier for Apollo than it was for Gemini and Mercury at less than 17,000 mph. It must enter the top of the earth's atmosphere to switch into an earthbound ballistic path. Apollo's air-friction heat will be 5,000° F, and the safe "reentry corridor" is only 40 miles wide, while the angle of attack (slant toward earth horizontal) must be kept between 5½° to 7½°.

But otherwise, quite like Mercury and Gemini, the bottom heat shield protects the crew as air resistance rapidly cuts velocity to a safe point for parachute deployment and landing.

From earth launch to earth touchdown, the total trip time will be some 198 hours, or about 8 days.

LUNAR ASTRONAUT EXPERIMENTS

Present plans call for the two LEM astronauts to stay from 4 to 34 hours on the moon's surface. The longer stay of 34 hours would allow each astronaut to step out of the LEM twice, for 3 hours at a time. As a margin of safety, their backpacks will be good for 4 hours, supplying oxygen, air conditioning, and cooling.

Restricted to an area close by the LEM, the astronauts will carry out various scientific tasks—collecting rock and soil samples, photographing nearby mountains, measuring the diameter of visible craters.

Also, the astronauts will be on the watch for surprises and may discover lunar phenomena totally unsuspected by earthly scientists.

If the landing site is in the right position, they will also photograph the "full earth," equal in brightness to 80 full moons.

APOLLO FOLLOW-ON PROGRAMS

The moon landing mission is not the end, but the beginning, of America's great space program. The moon will become the gateway to the solar system.

More Apollo landings are planned after the pioneer attempt, after which will come the Extended Apollo Project, for moon explorations in the early 1970's.

A totally new vehicle under study is the MOLAB (Moon Laboratory), an apparatus to travel 250 miles over the rough lunar surface, and providing 2 weeks of life support for two astronauts.

Gradually, a stable of specialized lunar vehicles that become operational could be ready for Project Moon Base—a permanent outpost with a moon ferry supply system. The first basic staff of six astronauts will increase as time goes on to dozens of men.

Their mission, in general terms, will be to explore a whole new world equal in total area (both sides of the moon) to Africa.

In time, a large astronomical observatory may be built on the moon, where airlessness provides unobstructed telescopic viewing of the outer universe. A lunar "spaceport" is another possibility, to serve interplanetary "traffic."

A separate branch of Apollo applications near earth could be use of the three-man spacecraft for a series of early space stations and manned laboratories in earth orbit.

Beyond that is the concept of larger space laboratories, with Apollo as the earth-to-orbit ferrycraft to deliver supplies and rotate personnel.

NASA FACTS format is designed for bulletin-board display uncut, or for 8 x 10½ looseleaf notebook insertion when cut along dotted lines and folded along solid lines. For notebook ring insertion, punch at solid dots in the margins.

NASA FACTS is an educational publication of NASA's Educational Programs and Services Office. It will be mailed to addressees who request it from: NASA, Educational Publications Distribution Center, AFEEE-1, Washington, D.C., 20546.

U.S. GOVERNMENT PRINTING OFFICE : 1965 OF—781-010

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 – Price 15 cents per copy